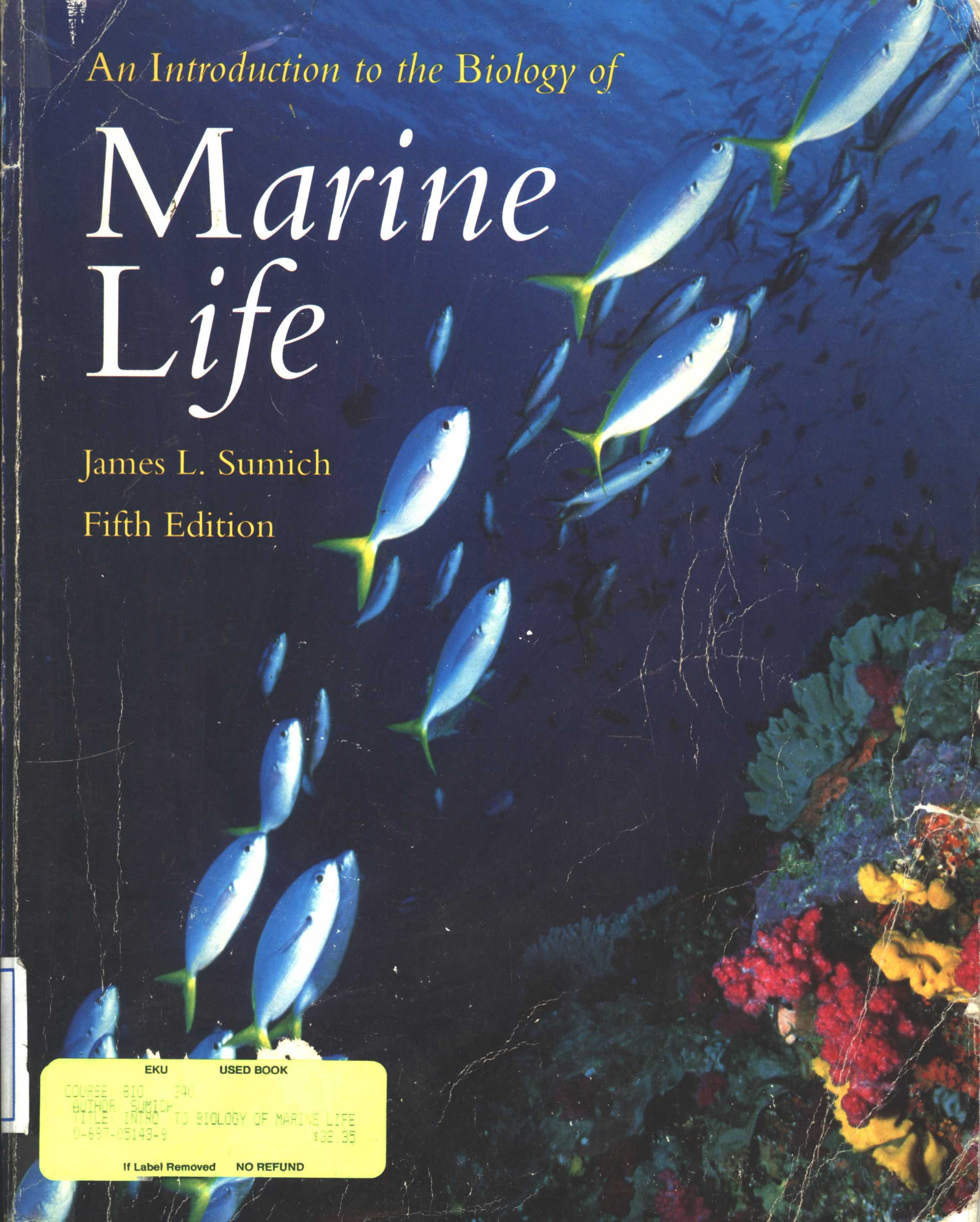
An Introduction to the Biology of

Marine Life

James L. Sumich

Fifth Edition



An Introduction to the Biology of Marine Life

Fifth Edition

James L. Sumich
Grossmont College

WCB Wm. C. Brown Publishers

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Library of Congress Catalog Card Number: 91-71936

ISBN 0-697-05143-9 (Paper)
0-697-13515-2 (Cloth)

Printed in the United States of America by Wm. C. Brown Publishers, 2460 Kerper Boulevard, Dubuque, IA 52001

10 9 8 7 6 5 4 3 2 1

Preface

An Introduction to the Biology of Marine Life was written to satisfy the demand for an introductory college-level text dealing with the biology of marine organisms. Recent developments in the field of marine biology have shown that courses in this subject provide an exciting and effective framework for illustrating basic biological principles. As a result, marine biology courses for the nonmajor or premajor student have become increasingly popular.

This text is written for the introductory marine biology student. No previous knowledge of marine biology is assumed. However, some exposure to the basic concepts of biology is helpful. Selected groups of marine organisms are used to develop an understanding of biological principles and processes that are basic to all forms of life in the sea. To build on these basics, information dealing with several aspects of taxonomy, evolution, ecology, behavior, and physiology of selected groups of marine organisms is presented. I have intentionally avoided adopting one of these major subdivisions as the framework of this text. Biology is an inclusive term, and a student's initial venture into this field should provide some flavor of the mix of disciplines that constitutes modern biology.

Scope of Subject Matter

This text includes more material than the typical student can assimilate in a semester. Instructors can select and mold the material to match their teaching styles and time limitations. The accompanying instructor's manual provides suggestions for use of this text, with judicious use of outside supplementary readings, in a two-quarter or two-semester course.

Sequence of Topics

As in most textbooks, each topic is developed after all have been first introduced in a general overview. Consequently, the sequence of topics is somewhat arbitrary and is intended to be flexible. The first chapter consists of an introduction to the marine environment. Chapter 2 examines the general features of life in the sea and how it has evolved to the present. Chapter 3, a survey of marine animal groups, is included here to avoid cumbersome definitions and descriptions in later discussions. Chapters 4 and 5 describe marine primary producers and examine the major factors that shape the pattern of marine primary productivity. Chapter 6 discusses estuaries as a reduced-scale analogy of the world ocean, its inhabitants, and their interactions. Chapters 7, 8, 9, and 10 emphasize the roles of marine organisms in divergent marine communities. Chapters 11 and 12 examine structural and physiological adaptations necessary to adequately fill those roles. The final two chapters offer a perspective for understanding the effects of human intervention upon marine ecosystems, including fishing (chapter 13) and pollution (chapter 14).

Student Aids

Each chapter contains numerous illustrations, graphs, and charts to assist students in visualizing the concepts presented. End-of-chapter summaries, questions for discussion, and supplementary reading lists encourage further in-depth exploration of covered topics. Additional references, listed at the end of the text, will be useful to students who have the enthusiasm and communication skills necessary to cope with the challenges of reading original literature.

Supplementary Materials

Instructor's Manual

The Instructor's Manual offers a variety of course schedules, chapter summaries, film and video sources, and sample test questions for each chapter.

Transparencies

Fifty two- and five-color acetate transparencies are available with this text. The transparencies are taken from the text and represent figures that merit extra visual review and discussion. These images can also be ordered as a slide set.

TestPak

wcb TestPak, a free, computerized testing service, simplifies testing while offering you flexibility. Two convenient TestPak options are available:

—Use your Apple® IIe, Apple® IIc, Macintosh or IBM PC to pick and choose test questions, edit them, and add your own questions. We can send you program and test item diskettes for this purpose.

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Materials for **Field Study**

Since I have avoided regional limitations where practical, this text is not designed for use as a detailed field guide for local marine organisms; however, several regional identification and field guides are listed in Appendix C. A companion text, *Laboratory and Field Investigations in Marine Biology,* by J. L. Sumich and G. H. Dudley, is available for courses emphasizing field or laboratory experiences.

N*ew to this* **Edition**

The widespread and positive reception of the four previous editions of this text continues to be encouraging. This edition represents a continuing effort to better meet the needs of those who use the text. The many suggestions and comments from readers have been considered in the changes that were made. Two new chapters, chapter 9 (Coral Reefs) and chapter 14 (Ocean Pollution), have been added. Information on deep-sea hot springs and their associated bacterial production, primary productivity in polar oceans, air-breathing tetrapod groups, and many other topics have been added or expanded significantly. Most existing illustrations have been revised, and numerous new ones have been added, all with full-color presentation, to better complement the text material.

List of **R***eviewers*

The following critical reviewers provided in-depth analyses of individual chapters and made many valuable suggestions concerning the final shape and content of the text:

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Market Research Respondents

We would like to thank the following adopters of the third edition for their help in preparing the current edition. Each contributed greatly to our understanding of the relative strengths and weaknesses of the third edition.

Genevieve Anderson, *Santa Barbara City College*
Jonathon N. Baskin, *Cal Poly University, Pomona*
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W. Herbert Wilson, Jr., *Northeastern University*
Melvin B. Zucker, *Skyline College*

Acknowledgments

Much credit for the development of this text goes to students and instructors who have used previous editions and have offered valuable comments and criticisms. I thank my instructors of the past and colleagues of the present for their contributions to my education and to this book. Special thanks also go to the many individuals and institutions that graciously supplied many of the photographs. Most of the biological illustrations are the work of a fine artist, Steve Haney. Finally, I thank my present and former students for their interest and enthusiasm in discovering rewarding methods of communicating this information.

James L. Sumich

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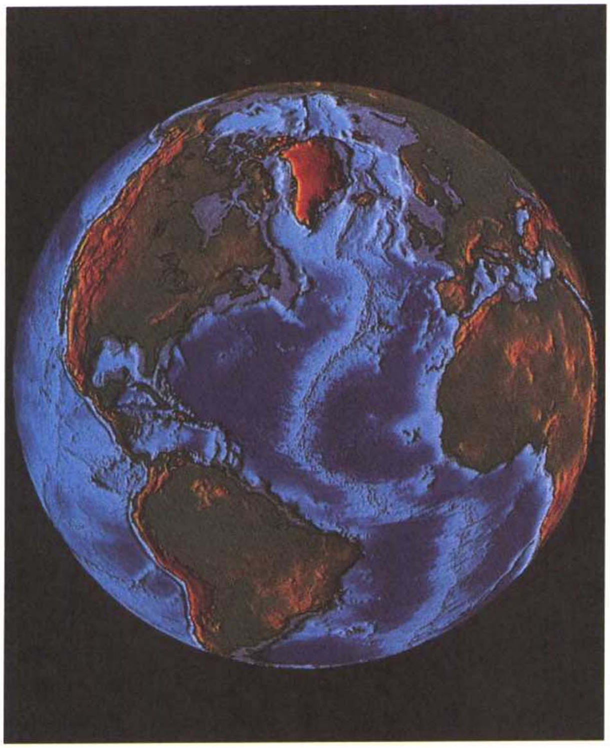
Chapter 1



A synthetic satellite view of the North Atlantic Ocean Basin

Courtesy National Aeronautics and Space Administration

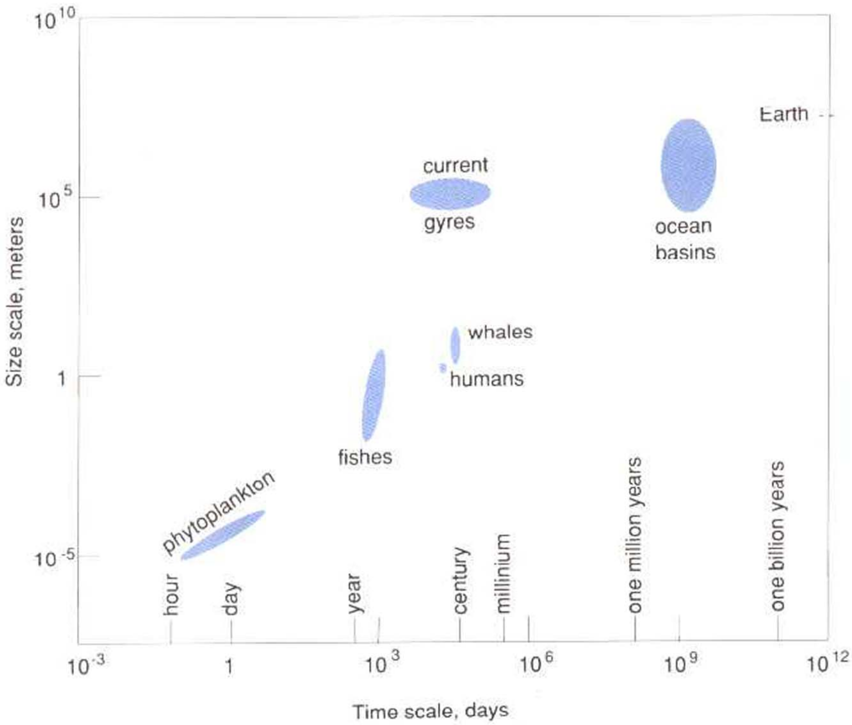


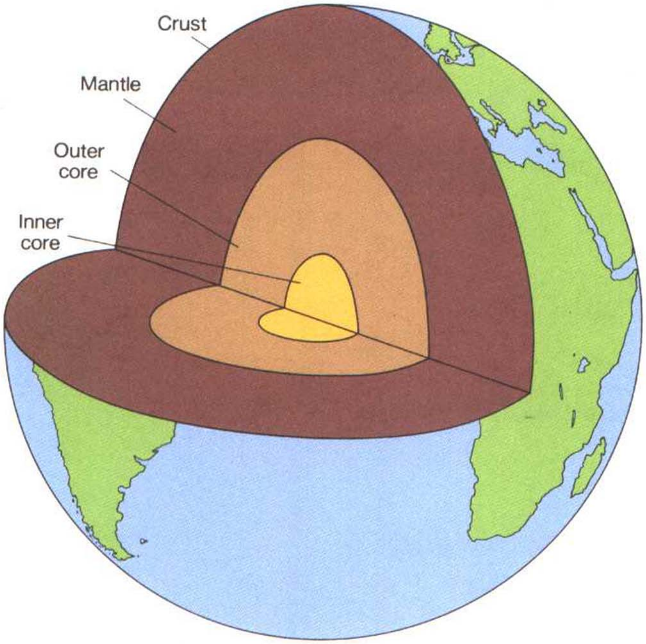
Figure 1.1
Some important marine features with appropriate time and size scales

The ocean environment is home to a tremendous variety of living organisms highly adapted to the special conditions of the sea. The general features of these organisms and the variety of marine life itself are products of the many properties of the ocean habitat. This chapter will provide a survey of the developmental history and present geography of the ocean basins and a general discussion of some properties of seawater and of ocean circulation processes.

You need to develop a special perspective to study the oceans. We naturally tend to see the world from a human viewpoint, with human scales of time and distance. To begin to understand the marine environment of earth and how it evolved to its present form, you must broaden your perspective to include very different time and distance scales. Terms such as young and old or large and small have limited meaning unless placed in some manageable context. Figure 1.1 compares space and time scales for a few common oceanic features and inhabitants. Throughout this book, these scales will be revisited and others will be introduced to help you develop a practical sense of the time and space scales experienced by marine organisms.

The Changing Marine Environment

Our solar system, including the earth, is thought to have been formed approximately 4.7 billion years ago. Modern theories on the origin of the solar system suggest that the planets aggregated from a vast cloud of cold gas and dust particles into clusters of solid matter. These clumps continued to grow as gravity attracted them together. As the earth grew in this manner, pressure



Layer	Depth range (km)	Thickness (km)	Density (g/cm³)
Crust			
Continental	10–65	55	2.8
Oceanic		10	3.0
Mantle	65–2900	2835	4.5
Outer core	2900–5300	2400	11.5
Inner core	5300–6370	1070	13.0
Total earth	0–6370	6370	5.5

Figure 1.2

A section through the earth, showing its density-layered interior structure. The crustal thickness is greatly exaggerated in order to show continents and ocean basins at this scale.

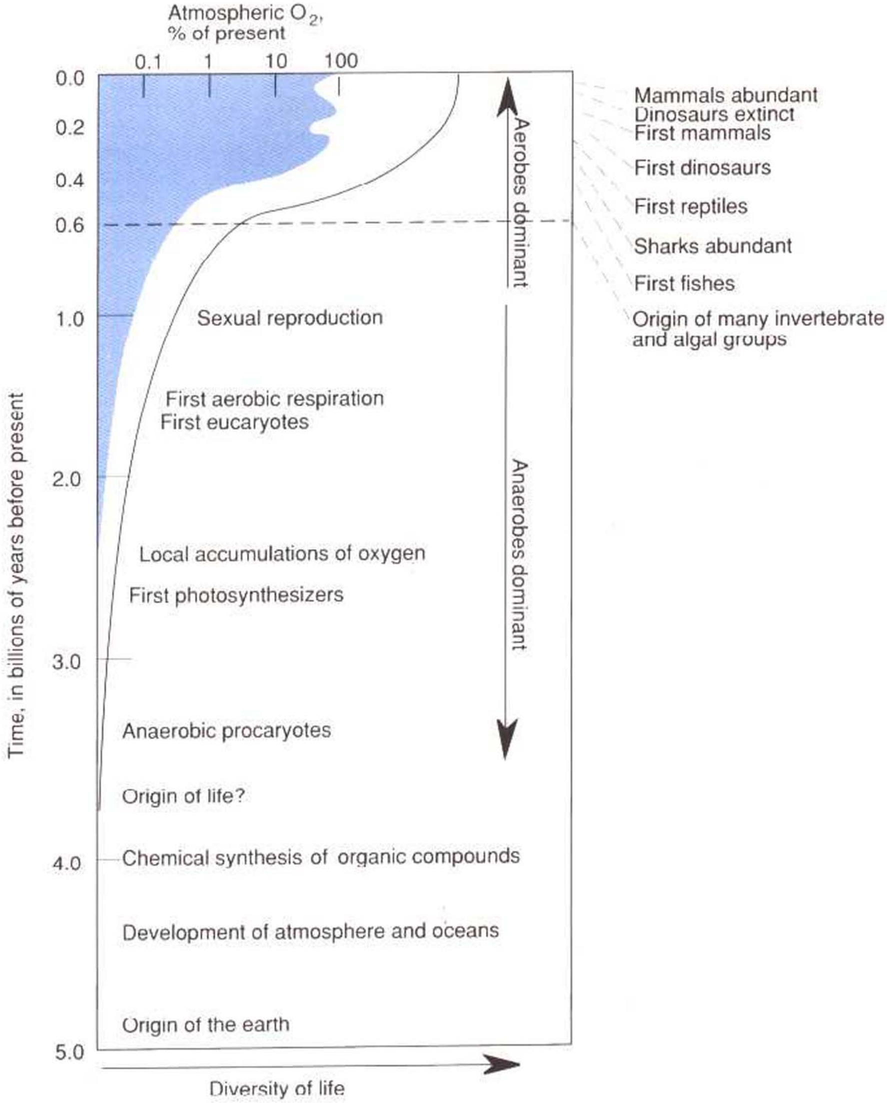
from the outer layers compressed and heated the earth's center. Aided by heat from decay of radioactive elements, the interior of the earth melted. Iron, nickel, and other heavy metals settled to the core, while the lighter materials floated to the surface and cooled to form a thin crust (figure 1.2).

Numerous volcanic vents poked through the crust and tapped the upper mantle for liquid material and gases that were then spewed out over the surface of the young earth, and a primitive atmosphere developed. Water vapor was certainly present. As the water vapor condensed, it fell as rain, accumulated in depressions on the earth's surface, and formed embryonic oceans. Atmospheric gases dissolved into accumulating seawater, and ions, dissolved from rocks and carried to the seas by rivers, added to the mixture, eventually creating seawater.

Since their initial formation, ocean basins have experienced considerable change. New material derived from the earth's mantle has extended the continents so that they are now larger and stand higher than at any time in the past. The oceans have kept pace, getting deeper with accumulations of juvenile water from volcanic gases and of chemical breakdown of rock. Earth's early life forms (represented by fossils older than about one billion years) had a significant impact on the character of their physical environment. Free oxygen (O_2) was produced in increasing amounts by microscopic photosynthetic cells. The O_2 content of the atmosphere 600 million years ago was probably about 1% of its present concentration. It was not much, but it is believed to have been the turning point, the time when organisms utilizing O_2 (in aerobic respiration) became dominant and organisms not utilizing O_2 became less prevalent.

The evolution of more complex life-forms using increasingly efficient methods of energy utilization set the stage for an explosion of marine life forms. By 500 million years ago, most major groups of marine organisms had made

Figure 1.3
A summary of some biological and physical milestones in the early development of life on earth. The lower curve represents the relative diversity of life; the upper curve represents the O_2 concentration of the atmosphere. Several of the terms used here will be defined in Chapter 2.



their appearance. Worms, sponges, corals, and the immediate ancestors of terrestrial animals and plants were abundant. But life could only exist in the sea at that time, where a protective blanket of seawater shielded it from harmful ultraviolet radiation.

As O_2 became more abundant in the upper atmosphere, some of it was converted to **ozone** (O_3). The process of forming ozone absorbed much of the lethal ultraviolet radiation coming from the sun and prevented the radiation from reaching the earth's surface. The O_2 concentration of the atmosphere 400 million years ago is estimated to have reached 10% of its present level. The ozone derived from the additional O_2 screened out enough ultraviolet radiation to permit a few life-forms to abandon their sheltered marine home and colonize the land. Only recently have we become aware that industrialized society's increasing use of aerosols, refrigerants, and other pol-

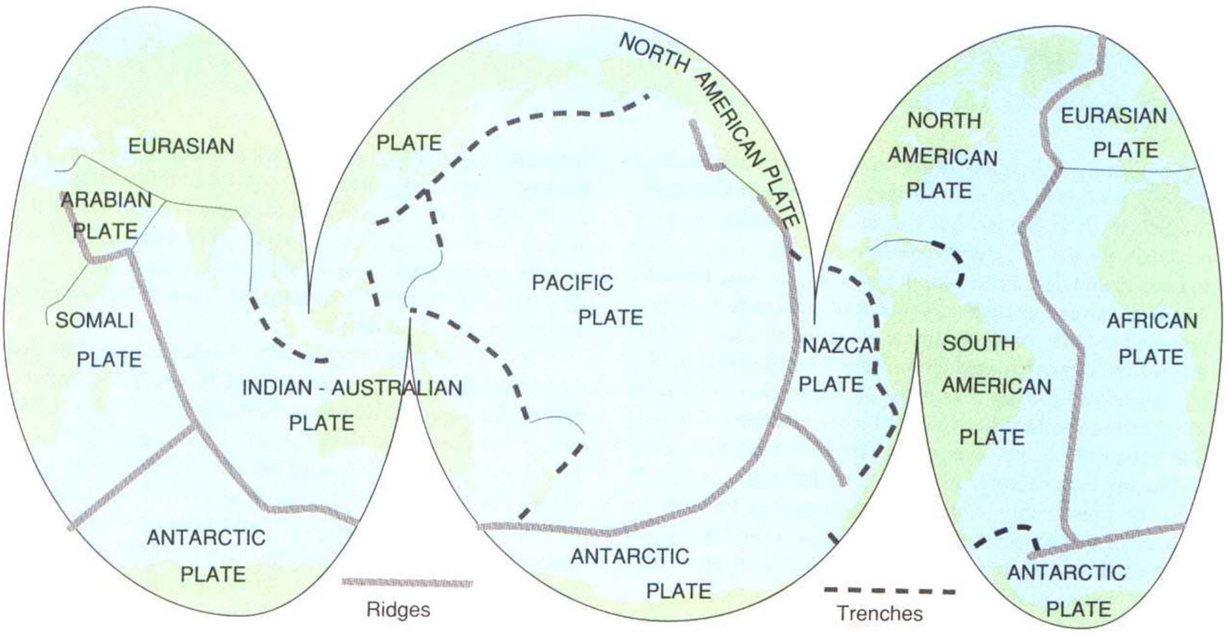


Figure 1.4
The major plates of the earth's crusts. Trenches are shown with dashes, ridges and rises with hatching. Compare the features of this map with those of figures 1.9 and 7.21.

lutants is gradually depleting this protective layer of ozone. Figure 1.3 summarizes significant events of the origin and early development of life on earth.

In the early part of this century, Alfred Wegener proposed that the oceans were changing in other ways. Wegener developed a detailed hypothesis of **continental drift** to explain several global geological features, including the remarkable jigsaw-puzzle fit of some continents (especially Africa and South America). He proposed that our present continental masses had drifted apart following the breakup of a single supercontinent, **Pangaea.** His evidence was ambiguous, and most scientists remained unconvinced. It was not until the early 1960s that new and telling evidence elicited wider endorsement by the scientific community. The early cruises of the *Glomar Challenger* (box 1.1) provided the telling evidence that verified Wegener's hypothesis.

The evidence that supports the closely related concepts of **seafloor spreading** and **plate tectonics** indicates the earth's crust is divided into a number of giant irregular plates (figure 1.4). These rigid plates float on the more dense and slightly plastic mantle material. Each plate is bounded by oceanic trench and ridge systems, and some plates include both oceanic and continental crusts. New oceanic crustal material is formed continually along the axes of oceanic ridges and rises. As the crustal plates grow on either side of the ridge, they move laterally in opposite directions, carrying bottom sediments and attached continental masses with them (figure 1.5).

In 1977, a remarkable discovery of new marine animal communities associated with seafloor hot water vents was made by scientists working in the deep-diving research submersible, *Alvin.* These vents are integral parts of some oceanic ridge or rise systems (figure 7.21). Members of these and other recently discovered deep-sea communities are discussed in chapter 7.

The changes that seafloor spreading and plate tectonics have wrought on the shapes and sizes of the oceans have been impressive. The African continent is drifting northward on a collision course with Europe, relentlessly

Box 1 *Three Voyages in Different Dimensions*

Primitive humans must have explored the marine portion of their immediate environment very early in their history, but few of their discoveries were recorded. By 325 B.C., Pytheas, the Greek explorer, had sailed to Iceland and developed a method for determining **latitude.** About a century later, Eratosthenes of Alexandria, Egypt, provided the first known estimate of the earth's size, its first dimension. His calculated circumference of 45,000 km was only about 12% greater than today's accepted value of 40,000 km. During the Middle Ages, Vikings, Arabians, Chinese, and Polynesians sailed over major portions of earth's oceans. By the fifteenth century, all the major inhabitable land areas were occupied; only Antarctica remained untouched by humans. Even so, precise charting of the ocean basins had to await three key developments, each one associated with its own voyage of discovery.

Between 1768 and 1779, James Cook, the English navigator, conducted three exploratory voyages, mostly in the Southern Hemisphere. He was the first to cross the Antarctic Circle and to understand and conquer scurvy (a disease caused by a deficiency of vitamin C). He is best remembered as the first global explorer to make extensive use of the marine **chronometer** developed by John Harrison, a British inventor. The chronometer, a very accurate shipboard clock, established the **longitude** of any fixed point on the earth's surface. Together with Pytheas's 2000-year-old technique for fixing latitude, accurate positions of geographic features anywhere on the globe could be established for the first time, and our two-dimensional view of the earth's surface was essentially complete. Today, coastal LORAN stations and satellite-based positioning systems permit individuals to determine their position to within a few tens of meters anywhere on earth.

In 1882, one century after Cook's voyages, the first truly interdisciplinary global voyage for scientific exploration of the seas departed from England. The H.M.S. *Challenger* was converted expressly for this voyage. The voyage lasted over three years, sailed almost 125,000 km in a circumnavigation of the globe, and returned with such a wealth of information that fifteen years and fifty large volumes were required to publish the findings. During the voyage, 492 depth soundings were made. These soundings traced the outlines of the Mid-Atlantic Ridge, plumbed the Mariannas Trench to a depth of 8185 m, and filled in rough outlines of the third dimension of the world ocean, its depth.

In 1968, a new and unusual ship, the *Glomar Challenger*, was launched to probe time, the fourth dimension of the oceans. Equipped with a deck-mounted drilling rig, the *Glomar Challenger* was capable of drilling into the seafloor in water over 7000 m deep. Within two years, the *Glomar Challenger* recovered vertical sediment core samples from enough sites on both sides of the Mid-Atlantic